Florence Weber

LICHENOMETRIC DATING IN THE CENTRAL ALASKA RANGE

by
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ABSTRACT

To establish a lichenometric dating scale for the Delta River area of the central Alaska Range, a tentative growth curve for Rhizocarpon geographicum was determined based upon lichen diameters on dated Recent moraines of Black Rapids and Canwell Glaciers. The ages of these prominent moraines, whose terminal sectors lie below tree-line, were dated by dendrochronology to be 1650(?) and 1830. Maximum-diameter Rhizocarpon geographicum on the 1830 terminal moraine of Black Rapids Glacier average 24 mm. Lichens could not be measured on the 1650(?) terminal moraine. A preliminary growth rate curve for Rhizocarpon geographicum was constructed in the Canwell Glacier area where maximum-diameter lichens on the 1830 moraine average 30 mm and on the 1650(?) moraine average 144 mm.

The prominent Recent moraines of nearby Gulkana and College Glaciers, which lie entirely above tree-line, were dated by comparison of maximum-diameter Rhizocarpon geographicum with the preliminary growth curve and were determined to have been formed by advances in 1580(?), 1650(?), 1830, and 1875. Maximum-diameter Rhizocarpon geographicum in the Gulkana-College Glacier area average 9 mm on 1875 moraines, 31 mm on 1830 moraines, 137 mm on 1650(?) moraines, and 177 mm on 1580(?) moraines.

The growth rate of Rhizocarpon geographicum in the central Alaska Range compares favorably with growth rates recorded in the Alps.

INTRODUCTION

General statement

To establish a lichenometric dating scale for the Delta River area of the central Alaska Range a tentative growth curve for Rhizocarpon geographicum was determined based upon lichen diameters on Recent moraines which have been dated by dendrochronology. The ages of Recent moraines which lie entirely above treeline were determined by extrapolating the maximum sizes of Rhizocarpon geographicum on these moraines to the tentative growth curve.

History of lichenometry

For decades observers in polar and alpine climates have noticed the very slow colonization by lichens on newly-exposed rock surfaces such as are found in front of retreating glaciers or around large melting snow patches. Early investigations were made in the Alps where historic records accurately locate morainal positions (Arnold, 1868-1898; Klebelsberg, 1913; Frey, 1922, Faigri, 1933; Negri, 1934; Friedel, 1938a, 1938b; Mattick, 1941; and Lüdi, 1945). More recent work in the Alps has been done by Beschel (1950, 1957a, 1958a, 1958b) and Heuberger and Beschel (1958); in Sweden by Bergström (1954), Larrson and Logewall (unpublished manuscript) and Stork (1963); in Norway by Bornfeldt and Österborg (1958); in West Greenland by Beschel (1959, 1961b); in the Canadian Archipelago by Beschel (1961a, 1963a, 1963b), Ives (1962), and Andrews and Webber (1964); and in central Africa by De Heinzelin (1953), De Heinzelin and Mollaret (1956) and Bergström (1955). Beschel (1957b) suggests a cooperative project to obtain reliable data on lichen diameters and growth rates from definite localities and to assemble at the Montreal Office of the Arctic Institute a collection of lichen photographs from all over the world.

Principles of lichenometry

Lichenometry is a relatively new method by which one can date recently exposed rock surfaces or recently active geologic processes in treeless areas by measuring the rate of lichen growth. This tool fills the gap in dating between the present and the existing minimum limit of isotope dating. Lichenometry is based on the slow, constant increase of individual plant diameters. Once the growth rate is known the age of a feature or process is determined by measuring the diameters of lichen thalli growing on a critical surface. The length of life of the lichen species used imposes a limit on the ages of exposed surfaces which can be determined by lichenometry.

Growth rates

Crustaceous lichens grow extremely slowly. A freshly-exposed rock surface is sprayed with wind- and water-borne spores and fragments of older lichen stock which become lodged in capillary cracks or small pockets on the surface of the fresh rock face (Beschel, 1950, p. 1). Here, if conditions permit, the lichen thalli grow.

Different lichen species grow at very different rates. Some species on a rock surface are microscopic even though they are the same age as the largest visible lichen of a different species on the same exposure. Also, lichens do not grow at constant rates throughout their entire life. During the early stages of growth the thallus is microscopic and a disproportionally long time interval passes before the individual plant becomes megascopically visible. Then begins a relative acceleration of its increase in size, which ceases at a specific diameter (Beschel, 1957a, p. 1). This period of relatively rapid growth ends after a few decades. Following the rapid growth period the increase of diameter per unit of time decreases and gradually approaches a constant rate which continues for many centuries for some species. This uniform growth period produces a straight line growth curve. Slow-growing lichens have a more constant growth rate compared to lichens which grow rapidly because climatic fluctuations less effectively alter the rate of diameter increase of slow-growing species. Under optimum environmental conditions lichens eventually reach a maximum diameter and the growth rate slows. It is not known how long fully mature lichens will remain in place because they may be removed by weathering, plant competition, human disturbance, sand blasting, and other external processes.

Dating methods

Lichenometric methods are divided into two main types: direct and indirect. Until more is known about the growth rates of the various lichen species in different microenvironments, direct measurement of lichen thalli over long time intervals must remain the basis for any growth analysis (Beschel, 1961b, p. 1047). Frey (1922, 1959) has photographed and measured lichens for the longest time interval to date--37 years--and has noted little change in some individuals over this period of time. The long life span of lichens and the slow growth rates of these plants prevent direct growth rate determinations by one worker. A simplified lichen growth curve can be indirectly determined by measuring the diameters of the largest lichens growing on several surfaces of different known ages and plotting these sizes against the age of the lichens. The ages of lichens on other surfaces in the same area can then be determined from this curve.

The approach to growth rate curve construction varies considerably. Four different measuring methods are as follows. Beschel (1961b, p. 1047) concluded that only the oldest and largest thalli on each surface should be considered because of the large number of uncertainties involved. He considered that the largest lichens will represent individuals growing under optimum local conditions. This conclusion is based on the assumption that the rock surface had no lichens growing on it when the current colonies began to grow. Larrson and Logewall (unpublished manuscript) measured the diameters of at least five of the largest specimens of different lichens and computed the average size within a 25 m^2 area to determine the age of moraines in the Kebnekajse Massif of Sweden. Ives (1962, p. 200-201) measured between 40 and 100 examples of the largest Rhizocarpon geographicum in each locality in north central Baffin Island in an attempt to determine the magnitude of time since the drainage of the former ice-dammed lake of Barnes Ice Cap. In later work around the northwestern margin of the Barnes Ice Cap, Andrews and Webber (1964) marked out 8 by 8 meter quadrants at 25 meter intervals around the outer moraines of the Ice Cap and recorded the diameters of 50 of the largest thalli in each quadrant.

Limitations of lichenometry

The limitations of lichenometry are due to a lack of information pertaining to: (1) the nature of lichen growth rates and (2) the effects of varying microenvironments on growth rates. Changes in one or more of the extrinsic factors of lichen growth are thought to cause the rate of diameter increase to vary considerably, but at the present time no quantitative data are available on the parameters of microenvironments. No direct measurements of growth rates have been made for lichens because of the slow growth rates of these plants. Only a few indirect evaluations are available which are based on the size of lichens found on features of "known" age and in these cases the varying microenvironments have not been considered. Indirect measurements treat old, large thalli as though they had lived under the same conditions as small thalli on a much more recently exposed rock surface. The growth rates of lichens over the world have not been correlated because of the difficulties of interpreting climatic effects. Geologists and other scientists hoping to use lichenometry are forced to determine growth rates for their respective areas by utilizing other methods, such as dendrochronology and historic records.

The inability to determine the end of active growth also presents a problem in measuring age when growth is slow. Lichens are able to withstand extended periods of desiccation, thereby complicating the problem. Llano (1956, p. 131) stresses that with increasing age lichens lose their individuality when adjacent species coalesce, when the substrata disintegrates, or when the center of the plant disintegrates. The length of life of lichens varies considerably with relation to climate. Beschel (1961b, p. 1047) states that crustaceous lichens of the genera Rhizocarpon and Lecidea grow for a period of 600 to 1300 years in the Alps, 1000 to 4000 years in West Greenland, and perhaps longer in higher arctic and antarctic regions.

Dating of glacial movements is based on the assumption that when glaciers move over rock surfaces, these surfaces are scoured clean of any former lichen cover. Thus, one would expect rock surfaces exposed by retreating glaciers and boulders which are released from the ice to have no lichen. This seems to be generally true; however, Goldthwait (1960, p. 95) notes the occurrence of an undamaged lichen cover on a boulder at the bottom of Ice Cliff Glacier in the Nunatarssauq area of Greenland. These lichens were apparently still alive 30 m behind the ice front and were covered by a thickness of 42.5 m of glacial ice. Beschel (1961b, p. 1050) assumes that this boulder was covered by static ice in a protective pocket and he doubts that the lichens could survive their emergence. Beschel (1961a, p. 196) notes old live lichens and mosses which are partly just emerging from the melting nivation ice-sheets on Axel Heiberg Island in Arctic Canada. These lichens were permanently frozen and survived, whereas lichens in marginal snow banks did not. Dr. Leslie Viereck (oral communication, 1963) found undamaged large lichens on a very recent moraine of a glacier in the Tonzana River area which definitely had survived emergence from the glacier, but stresses this is a very unique occurrence.

Acknowledgements

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LICHENOMETRIC DATING IN THE CENTRAL ALASKA RANGE

General statement

To establish a lichen thalli growth rate and set up a lichenometric scale Reger measured lichen diameters on the two prominent Recent moraines of Canwell and Black Rapids Glaciers, whose termini lie in the Delta River valley (fig. 1). Dates of the glacial advances which formed these moraines and those of nearby Castner Glacier had been determined by dendrochronology to be about 1650(?) and 1830 (Péwé, unpublished data).

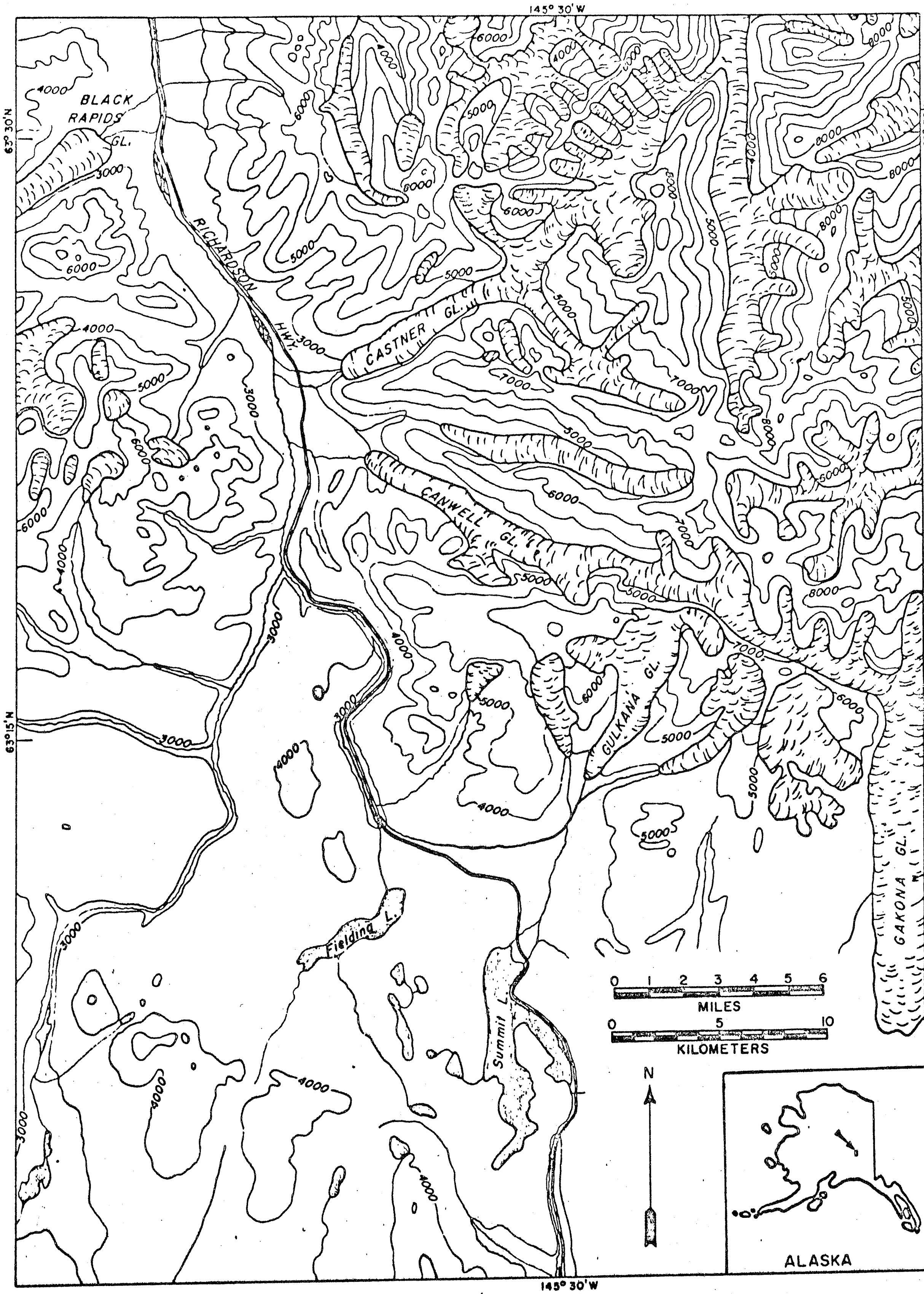

Figure 1. - Index map of the central Alaska Range showing locations of major glaciers. (Base after U.S. Geological Survey Mt. Hayes, 1950. Scale 1:250,000)

Dating of glacial advances by dendrochronology

Black Rapids Glacier

The terminus of Black Rapids Glacier is below tree-line at an elevation of 668 m. At least three prominent arcuate moraines indicate advances in Recent time (Péwé, 1951). The oldest end moraine is compound, has low relief, and has no ice core. It is rather continuous in form and has a dense growth of spruce, willows, alders and aspen. Boulders in this moraine are only sparsely covered with lichens. In 1951 Péwé noted spruce up to 6.3 cm in diameter and counted 144 annual rings on this moraine. Older trees could not be used because their cores were rotted. He concludes that this moraine was formed by an advance of Black Rapids Glacier in about 1650(?) because he found trees at least 228 years old with rotted cores on the outwash plain just in front of the moraine. It was considered that these trees could have been present on the plain prior to the advance and consequently survived the outwash of sediments from the proglacial streams, but this was not thought likely in view of the number of trees of this age found. A factor of 15 to 20 years was added to the tree ring dates because timberline conditions, severe winds, and shifting of ice-cored moraines prohibit tree growth for at least 15 to 20 years following formation of the moraines. A 4 year old spruce was the first tree found growing (in 1957) on the 1937 moraine of Black Rapids Glacier. The development of an incipient soil on the 1650(?) moraine suggests that the moraine is definitely older than 200 years. This age is also supported by data from Castner and Canwell Glaciers. A dense forest with 350 to 500 year old trees lies adjacent to the earliest Recent moraine of Black Rapids Glacier on the west side of the Delta River. This forest is not of first generation trees and is greatly different in maturity from the young forests on the adjacent moraines. The moraine is certainly younger than 400 to 500 years.

The second arcuate terminal moraine of Black Rapids Glacier lies about 0.8 km inside the oldest Recent moraine of the glacier. It is fresh appearing and has no turf cover, but an ice core is present in places. Boulders of this moraine are usually bare of lichens except where there is little or no ice core. Péwé measured spruce trees 4.6 cm in diameter on this moraine and counted 98 growth rings. Trees growing on a comparable end moraine of Castner Glacier were determined to be 102 years old in 1951. It is concluded that these moraines were the result of an advance of both glaciers in 1830, or about 120 years prior to 1951.

The 1937 advance of Black Rapids Glacier is well documented (Hance, 1937; Moffit, 1942; and Geist and Péwé, 1957). The terminal moraine of this advance is very fresh and has in most areas an actively melting ice core.

Canwell Glacier

The terminus of Canwell Glacier is below tree-line at an elevation of 758 m; therefore tree-ring dating could be utilized to determine the ages of the two prominent Recent terminal moraines (Péwé, 1957). The outer moraine is fragmentary, rather low in relief, and has no ice core. It is largely forested with primary spruce growth, is covered with a turf cover up to 0.3 m thick, and bears lichen-covered boulders in treeless areas. In 1951 Péwé measured first generation spruce up to 7.5 cm in diameter on this moraine and counted as many as 159 to 165 annual growth rings. A spruce log collected by Péwé in till of this moraine was determined to be less than 200 years old by radiocarbon dating in 1953 (W-268) (Rubin and Suess, 1956, p. 244). However, Meyer Rubin (written communication, 1964) stresses that the log could indeed be older than 200 years. The outer moraine is thought to be the result of a Canwell Glacier advance around 1650(?) because of its forest and soil development and comparable position (relative to the 1830 moraine) with the outer Recent moraine of Black Rapids Glacier.

The inner prominent end moraine of Canwell Glacier lies 0.8 km inside the outer moraine. It is composed of fresh rock and has some ice core remaining. There are few trees and no turf and lichen-bearing boulders are scant or absent. Péwé measured spruce up to 5.5 cm diameter growing at the base of the moraine and counted 102 annual growth rings. The moraine is thought to correlate with the 1830 moraine of Black Rapids and Castner Glaciers.

Summary of dendrochronology

The ages of Recent moraines in the central Alaska Range, with the exception of the 1937 terminal moraine of Black Rapids Glacier, are of necessity approximate and are based entirely on tree ring assessments on two prominent terminal moraines of Black Rapids, Castner, and Canwell Glaciers by Péwé (1951, 1957, unpublished data). It has been suggested by Viereck (oral communication, 1963) that the 1650(?) date obtained by dendrochronology may represent the earliest time at which trees grew in this area because tree-line is rising in parts of the Alaska Range. The 1650(?) moraine thus may be much older. However, Giddings (1941, p. 14) states that standing trees occur near the Recent terminal moraines of Black Rapids Glacier at higher elevations than the moraines. He adds that these trees are more than 500 years old since 3 inches (8 cm) of sound wood out of a possible 10-inch (25 cm) radius yields as many as 350 rings. Péwé also found trees as old as 350 to 500 years just outside the oldest Recent moraines of Castner and Black Rapids Glaciers. Therefore, it appears that trees definitely were in the area prior to 1650. The 1650(?) age of the older Recent moraines is supported by the incipient soil and alpine tundra cover developed on these features and the C-14 date from a log found in till of the 1650(?) Canwell Glacier moraine.

Trees were definitely in this area by 1830, so this date is well established and well correlated between glaciers. Because of the time lapse between morainal formation and the first growth of trees, these advances cannot be dated precisely by the age of trees growing on the various moraines.

Lichen sizes on Recent moraines

The establishment of the relative ages of the Recent moraines of Canwell and Black Rapids Glaciers made it possible to determine a standard lichen growth rate for the central Alaska Range. Reger measured lichen diameters on Recent moraines in terminal areas of Canwell and Black Rapids Glaciers, but found that results in these areas are misleading because of (1) sandblasting by winds blowing across nearby outwash plains and (2) the thick growth of moss, willow, alder, aspen and spruce. This was particularly true on the 1650(?) terminal moraines and true to a lesser degree on the 1830 moraines. Better results were obtained on the south lateral moraines of Canwell Glacier which are above tree-line.

Species and method

The following lichen species were collected by Reger from Recent moraines in the central Alaska Range and identified by Dr. W. A. Weber.

Agyrophora rigida (Du Rietz) Llano
Alectoria pubescens (L.) Howe
Cetraria cucullata (Bess.) Ach.
Cetraria hepatizon (Ach.) Vain.
Cetraria islandica (L.) Ach.
Cetraria nivalis (L.) Ach.
Cetraria tilesii Ach.
Cladonia amaurocraea (Florke) Schaer.
Cladonia coccifera (L.) Zopf
Cladonia deformis (L.) Hoffm.
Cladonia gracilis (L.) Willd.
Cladonia verticillata (Hoffm.) Schaer.
Cornicularia aculeata (Schreb.) Ach.
Dactylina arctica (Richards.) Nyl.
Lecanora sp. (L. intricata ? (Schrad.) Ach.)
Lobaria linita (Ach.) Rabenh.
Parmelia centrifuga (L.) Ach.
Parmelia stygia (L.) Ach.
Rhizocarpon geographicum (L.) DC.
Solorina crocea (L.) Ach.
Sporostatia testudinea (Ach.) Mass.
Stereocaulon sp. (Schreb.) Hoffm.
Thamnolia vermicularis (Sw.) Ach.
Umbilicaria cylindrica (L.) Del.
Umbilicaria hyperborea (Ach.) Hoffm.
Umbilicaria proboscidea (L.) Schrad.
Umbilicaria torrefacta (Lightf.) Schrad.

Rhizocarpon geographicum (fig. 2) is utilized for this study because (1) it is abundant in the central Alaska Range and is easily recognized in the field; (2) it has proven reliable in the Alps and provides a basis for comparison of lichen growth rates in the central Alaska Range with rates in other parts of the world; and (3) it shows the most apparent correlation between size and age of all the species present in the central Alaska Range.

Umbilicaria proboscidea, Umbilicaria torrefacta, and Umbilicaria hyperborea are abundant, but are not utilized because their size-age ratios do not appear constant in contrast to other areas. Larger individuals are found on 1830 moraines than on 1650(?) moraines, although they are more numerous on 1650(?) moraines. Umbilicaria cylindrica is abundant, but time restrictions did not allow a detailed study of this lichen even though its size-age ratio apparently is consistent. Umbilicaria spp. were measured at stations where Rhizocarpon geographicum are stunted or not present only as a means of correlating moraines.

To determine a lichen growth standard for the central Alaska Range Reger (1964) measured at least 10 of the largest Rhizocarpon geographicum,

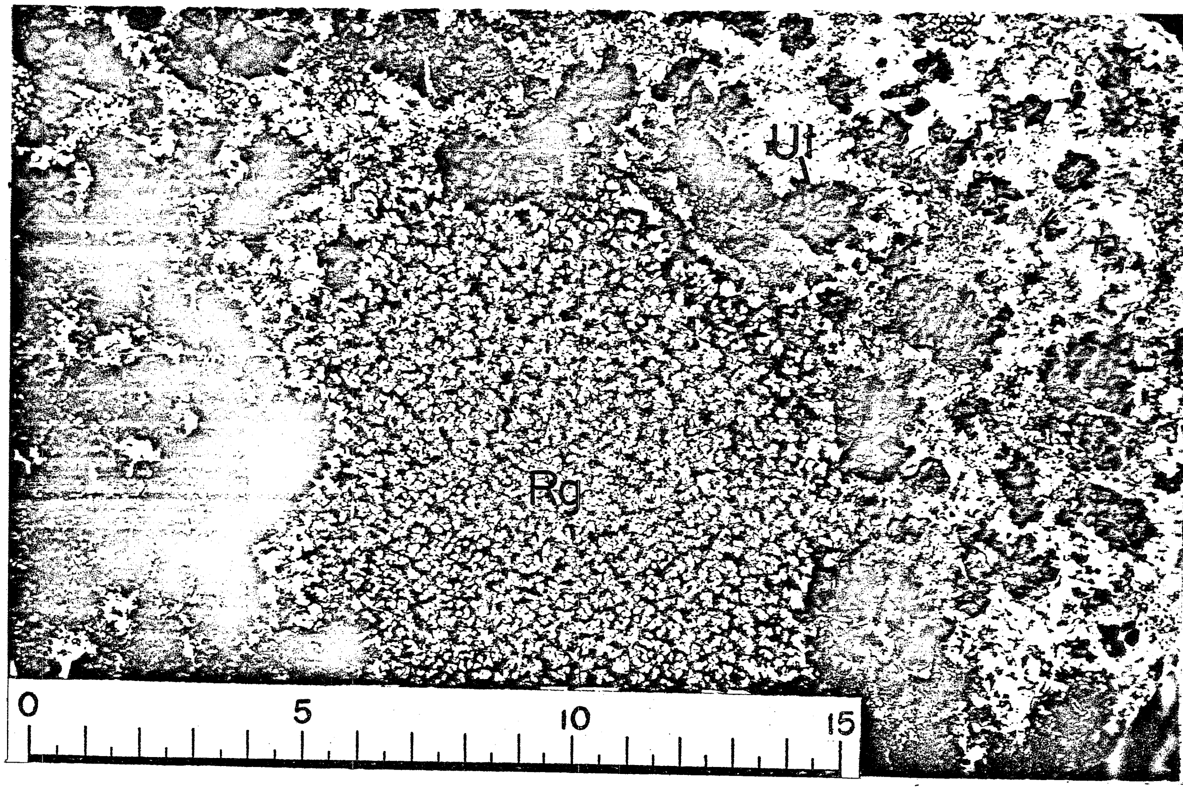

Figure 2. - Rhizocarpon geographicum (Rg) and Umbilicaria torrefacta (Ut) on quartz diorite boulder of 1650(?) east lateral moraine of Gulkana Glacier, central Alaska Range,, Alaska. Scale in centimeters. (Photograph by Troy L. Pewe, August 3, 1962).

Umbilicaria proboscides, or Umbilicaria cylindrica at each established station when possible. At each station Reger recorded[1] the lichen species measured, diameter in mm., altitude in meters, angle of exposure of the rock face, direction of exposure, estimated mean rock diameter and rock type, whether the habitat is sunny or shady, feet above ground, location and largest diameter of each species measured. Lichens were measured on the largest boulders because these were considered more stable than small boulders. The effect of varying lithology was minimized by measuring lichens on diorite or quartz diorite whenever possible.

Black Rapids Glacier

Results of lichen measurements on the Recent terminal moraines of Black Rapids Glacier are limited (fig. 3). Unfortunately there was insufficient time available to measure lichens on the lateral moraines of Black Rapids Glacier above tree-line where measurements would provide a much better basis for comparison with other glaciers in the central Alaska Range. The 1650(?) terminal moraine is thickly covered with spruce, aspen, willows, and alders and lichenometry is not applicable. Dead Rhizocarpon geographicum thalli 80 mm in diameter were observed on the east side of Delta River in the well-forested area and widely-scattered live thalli up to 30 mm in diameter were measured. Apparently the encroachment of thick vegetation in approximately 1830 altered the microenvironment to such an extent that pre-existing thalli were killed and the present live lichens represent a secondary colonization. On the 1650(?) terminal moraine west of Delta River, dead thalli up to 75 mm were observed and live thalli up to 40 mm were measured. Here the moraine is partly blanketed with sand, and dead lichen thalli show effects of sandblasting. Apparently lichens which grew on this moraine prior to 1830 were killed during the 1830 advance by windblown sand and picked up from the active outwash plain. Live lichen here are also thought to represent secondary colonization.

The largest Rhizocarpon geographicum on the 1830 terminal moraine of Black Rapids Glacier range from 11 to 43 mm in diameter and average 24 mm (fig. 3). Lichens were measured on large boulders on that part of the moraine which was not ice cored wherever possible.

Scattered Rhizocarpon geographicum up to 4 mm in diameter were measured on the 1937 terminal moraine, but these are on boulders of the outermost part of this moraine which may not have been ice cored in 1937. No thalli were seen on the ice cored 1937 terminal moraine in 1962--25 years after its formation.

The growth rate curve of Rhizocarpon geographicum on the Recent moraines of Canwell Glacier was constructed by plotting the average of maximum diameters of thalli on each moraine against time (fig.4). This curve may be used to represent the average growth rate of Rhizocarpon geographicum in the central Alaska Range. Unfortunately the lack of data from the 1650(?) moraine of Black Rapids Glacier does not permit construction of a growth curve for this glacier or comparison of the growth curves for Canwell and Black Rapids Glaciers at the present time. However, the lichen diameters on the 1830 moraines of both Canwell and Black Rapids Glaciers are well established and compare favorably (fig.4). The average maximum Rhizocarpon geographicum diameter on the

[1]All details recorded at each station are listed in Reger, 1964, Tables 1, 2, and 3.

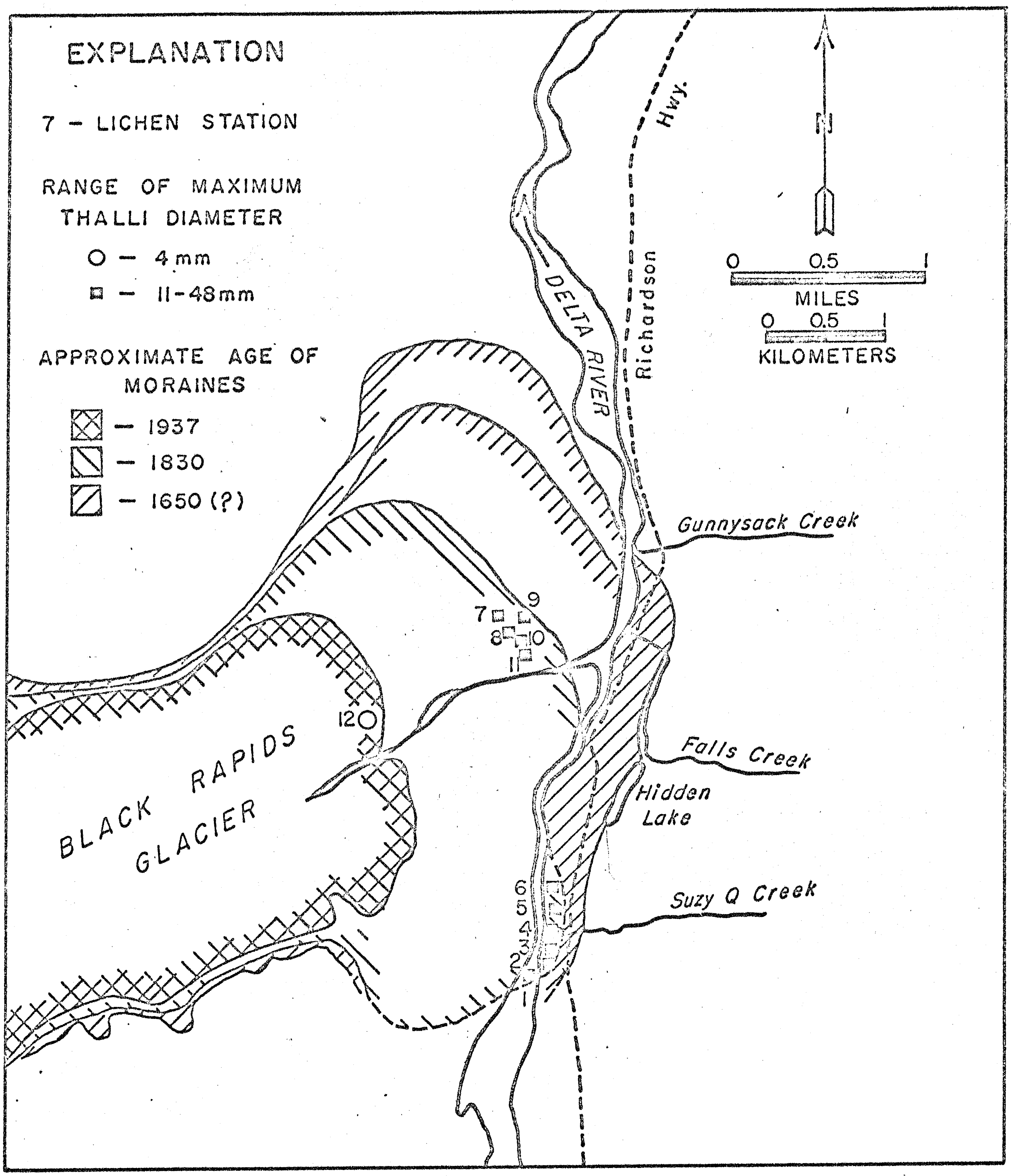

Figure 3. - Relationship of maximum-diameter Rhizocarpon geographicum size ranges to Recent moraines of Black Rapids Glacier, central Alaska Range. (Base after U. S. Army Map Service Mt. Hayes B-4 and C-4, 1951. Scale 1:50,000)

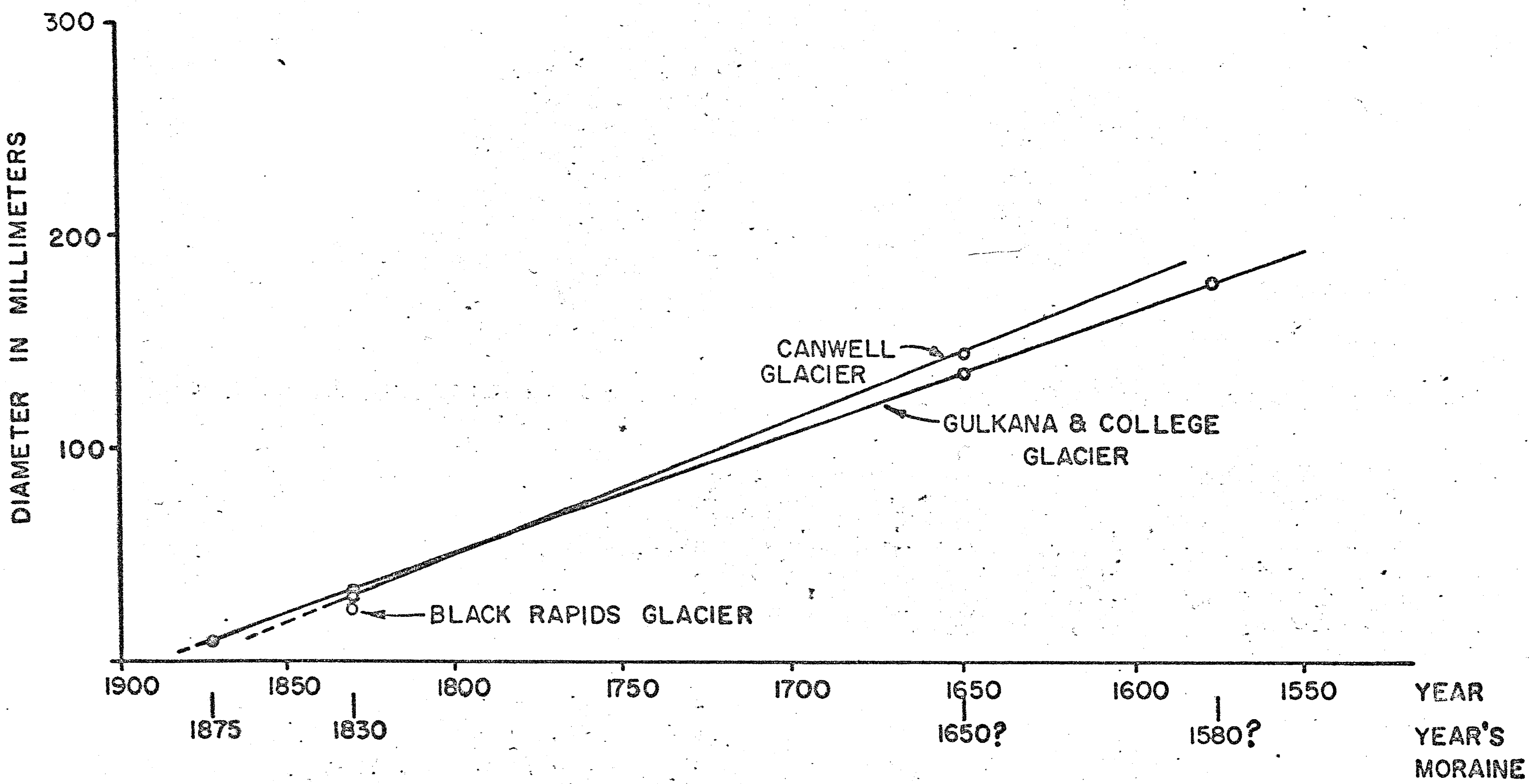

Figure 4.- Comparison of tentative growth rate curves of _Rhizocarpon geographicum_ at Canwell, Gulkana, and College Glaciers, central Alaska Range, Alaska.

1830 terminal moraine of Black Rapids Glacier is only 6 mm less than the average maximum diameter on the 1830 lateral and terminal moraines of Canwell Glacier; the average maximum 1830 lichen diameter on the terminal moraine of Black Rapids Glacier is only 2 mm less than the average maximum diameter of *Rhizocarpon geographicum* on the 1830 terminal moraine of Canwell Glacier.

Canwell Glacier

The largest *Rhizocarpon geographicum* on the south 1650(?) lateral moraine range from 132 to 161 mm in diameter and average 144 mm (fig.5). The thick moss and spruce cover on the fragment of the 1650(?) terminal moraine remaining is unfavorable for lichen growth and no thalli were observed.

On the 1830 lateral moraine of Canwell Glacier the diameters of the largest *Rhizocarpon geographicum* are 28 to 50 mm, but on the 1830 terminal moraine they are only 18 to 33 mm. The average size for both parts of the 1830 moraine is 30 mm.

Gulkana and College Glaciers

The determination of the growth rate curve of *Rhizocarpon geographicum* on the moraines of Canwell Glacier provides a scale which aids in dating the Recent moraines of nearby Gulkana and College Glaciers--moraines which lie above tree-line. Gulkana Glacier has four Recent moraines and College Glacier has two of which two of these moraines at each glacier were initially considered to correlate with the 1650(?) and 1830 moraines, respectively, of Castner, Canwell and Black Rapids Glaciers because of their position and topographic expression. Using these assumed dates and measuring maximum thalli diameters of *Rhizocarpon geographicum* on these prominent moraines a growth rate curve was constructed and compared with the growth rate curve for Canwell Glacier (fig.4). The curve for *Rhizocarpon geographicum* in the Gulkana-College Glacier area is almost identical with the growth curve of this lichen at Canwell Glacier, which supports the basic assumption that the prominent moraines of Gulkana and College Glaciers are equivalent to the 1650(?) and 1830 moraines at Canwell Glacier. Once the growth curve of *Rhizocarpon geographicum* for the Gulkana-College Glacier area was established, it was possible to date the two Recent moraines in the Gulkana-College Glacier area that apparently have no equivalent at Canwell Glacier. There moraines were determined to date from 1580(?) and 1875 (fig.4).

Gulkana Glacier - Of the four Recent moraines at Gulkana Glacier, the two *oldest moraines* form discontinuous ridges which lie just outside younger, continuous moraines. Boulders of the outermost Recent moraine bear anastomosing colonies. Maximum individual *Rhizocarpon geographicum* diameters range from 155 to 198 mm (fig. 6) and have an average diameter of 177 mm. This moraine has no equivalent at Canwell Glacier, but may represent an advance in about 1580 (?).

Inside the 1580(?) moraine is a prominent lateral moraine on which maximum diameters of *Rhizocarpon geographicum* range from 115 to 175 mm and average 137 mm. This moraine is thought to be closely equivalent to the 1650(?) moraine of Canwell Glacier where the same lichen averages 144 mm in diameter (fig.4).

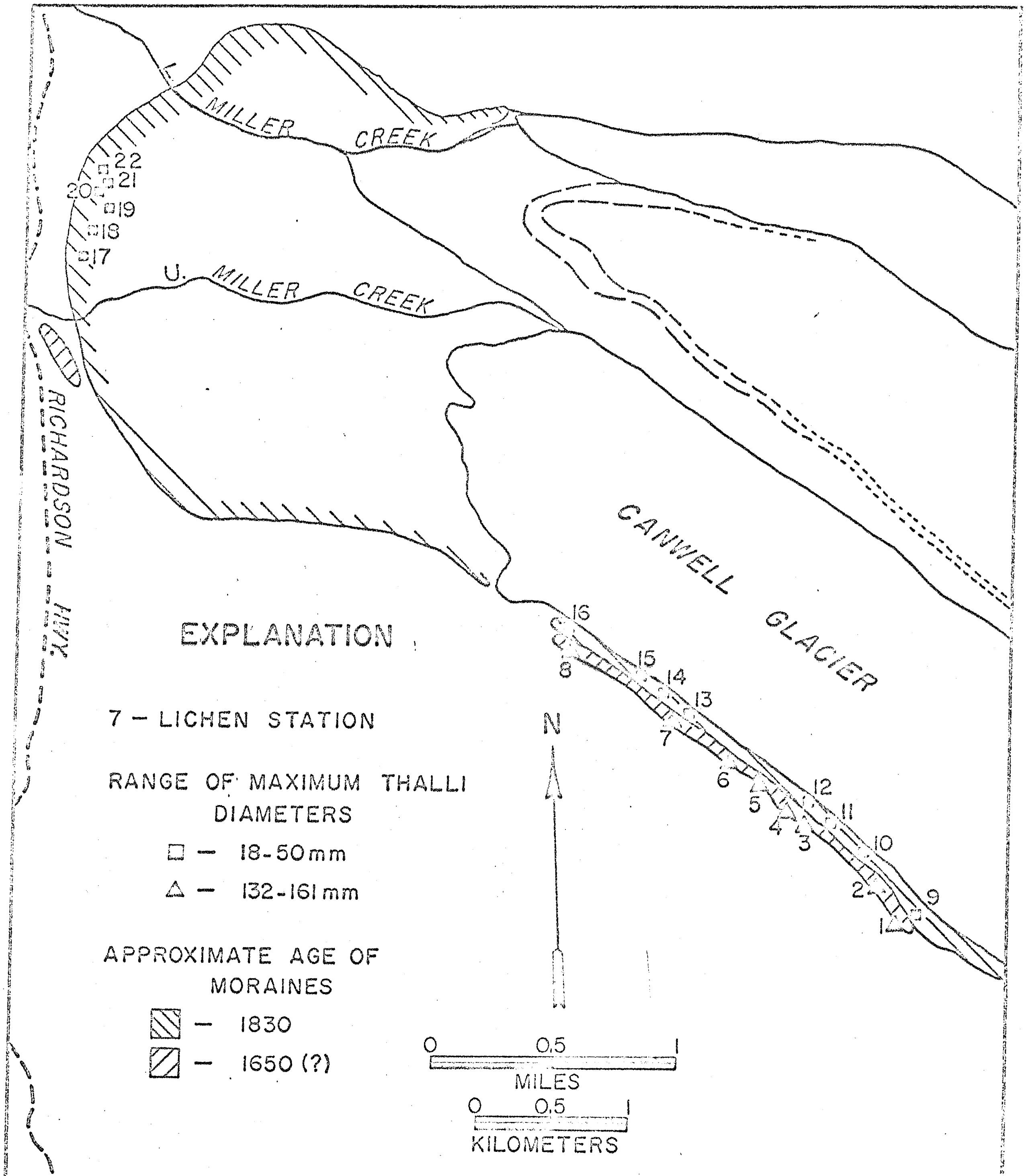

Figure 5 - Relationship of maximum-diameter Rhizocarpon geographicum size ranges to Recent moraines of Canwell Glacier, central Alaska Range. (Base after U. S. Geological Survey Mt. Hayes B-4. Scale 1:40,000)

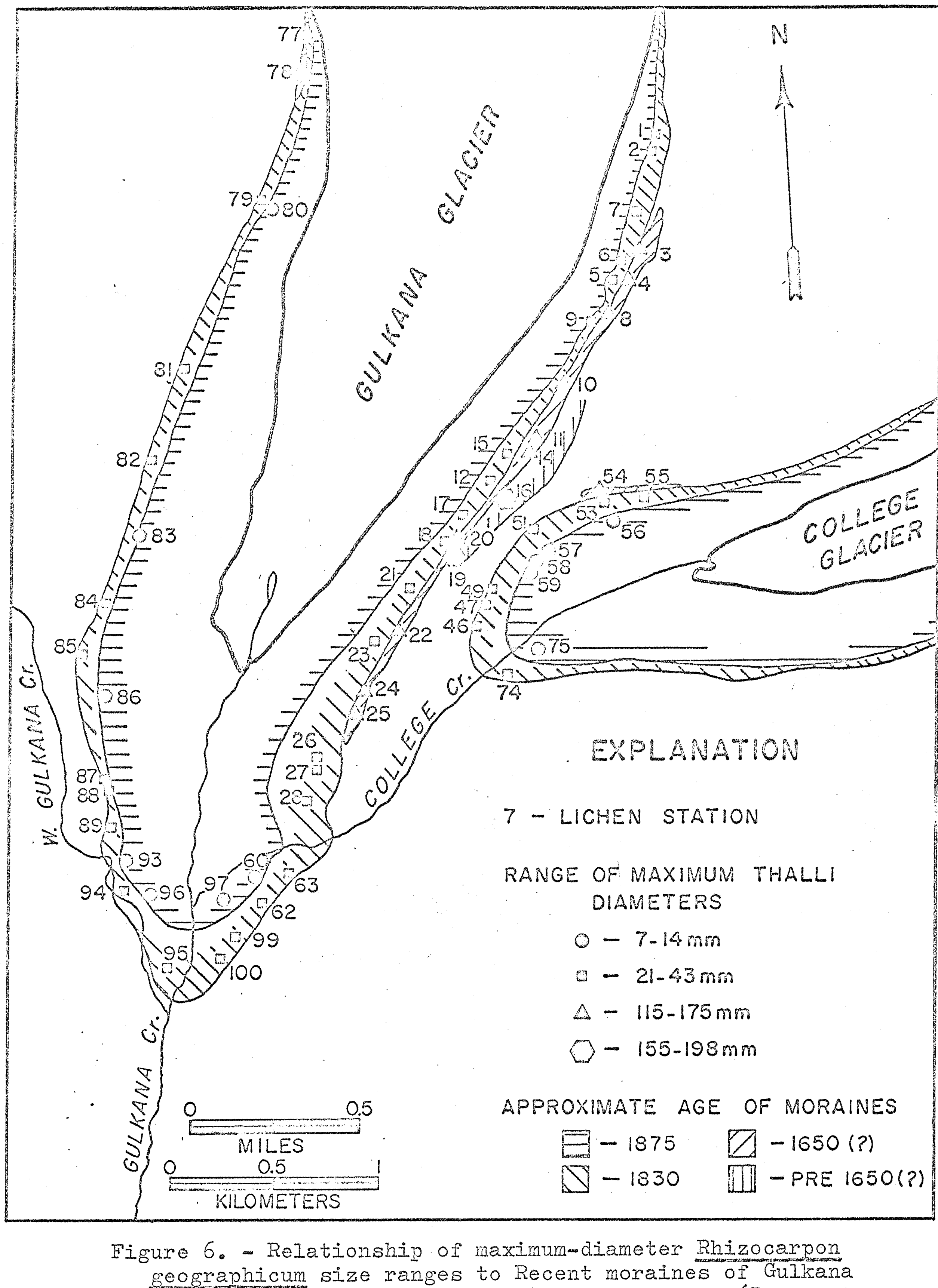

Figure 6. - Relationship of maximum-diameter Rhizocarpon geographicum size ranges to Recent moraines of Gulkana and College Glaciers, central Alaska Range. (Base after air photograph by U. S. Navy, 9 Aug 57, identification no. 004 VVAP-61 Det "T" USN 10/c)

The 1830 moraines of Canwell and Black Rapids Glaciers have a well defined equivalent at Gulkana Glacier. On this moraine the largest Rhizocarpon geographicum range from 21 to 43 mm in diameter with an average maximum diameter of 29 mm, as compared to 30 mm on the 1830 moraine of Canwell Glacier and 24 mm at Black Rapids Glacier (fig.4).

The youngest moraine at Gulkana Glacier is much smaller than the other three Recent moraines, but is well defined and probably represents a minor advance. The range of maximum Rhizocarpon geographicum on this moraine is 7 to 14 mm in diameter and the largest examples of this species average 10 mm in diameter. Gulkana Glacier advanced and formed this moraine in approximately 1875 (fig. 6).

College Glacier - The equivalency of two Recent moraines of Gulkana Glacier with the moraines of College Glacier has been established by lichen measurements (fig. 6). The ages of the two oldest Recent moraines at College Glacier are placed at pre-1580(?). Boulders of these moraines are completely, or almost completely covered by solifluction deposits and lichen measurements were possible at only one station on the inner moraine. The maximum size of Rhizocarpon geographicum at this station is 125 mm. These moraines have no terminal equivalents.

The most conspicuous arcuate moraine of College Glacier dates from about 1830 (fig. 6). The average maximum diameter of Rhizocarpon geographicum on this moraine is 36 mm and maximum diameters of this lichen range from 29 to 50 mm.

The youngest moraine of College Glacier corresponds to the 1875 moraine of Gulkana Glacier. The maximum diameter of Rhizocarpon geographicum here is from 6 to 10 mm and averages 8 mm.

Effects of microenvironment on lichen growth in the central Alaska Range

Apparently the most important decisive factors affecting lichen development in the central Alaska Range are (1) stability of substratum, (2) sunlight, and (3) moisture.

The development of lichen cover on moraines is dependent on the size and rate of ice core melting in these moraines. Ice cores decrease in volume and rate of melting with increasing age and ice cores melt more rapidly at lower elevations than at higher elevations. No lichens are present on actively moving substrata such as moraines with shallow, rapidly melting ice cores. The 1875 moraines of Gulkana and College Glaciers have a scattered and spotty lichen cover which is probably due primarily to a melting ice core. Moraines of 1830 age have smaller ice cores and the lichen cover is better developed. The lichen cover on 1650(?) and 1580(?) moraines is very thick and no ice core is present.

The assumption was made that maximum-diameter lichens are growing in optimum microenvironmental conditions. The dip directions of the rock face hosting the largest thalli in the Gulkana and College Glacier area (fig. 7a and 7b) were plotted and found to have a dominant southwest orientation. These measurements were taken on slopes of widely varying angle and direction, so the results are not weighted by local topography. This dominant orientation

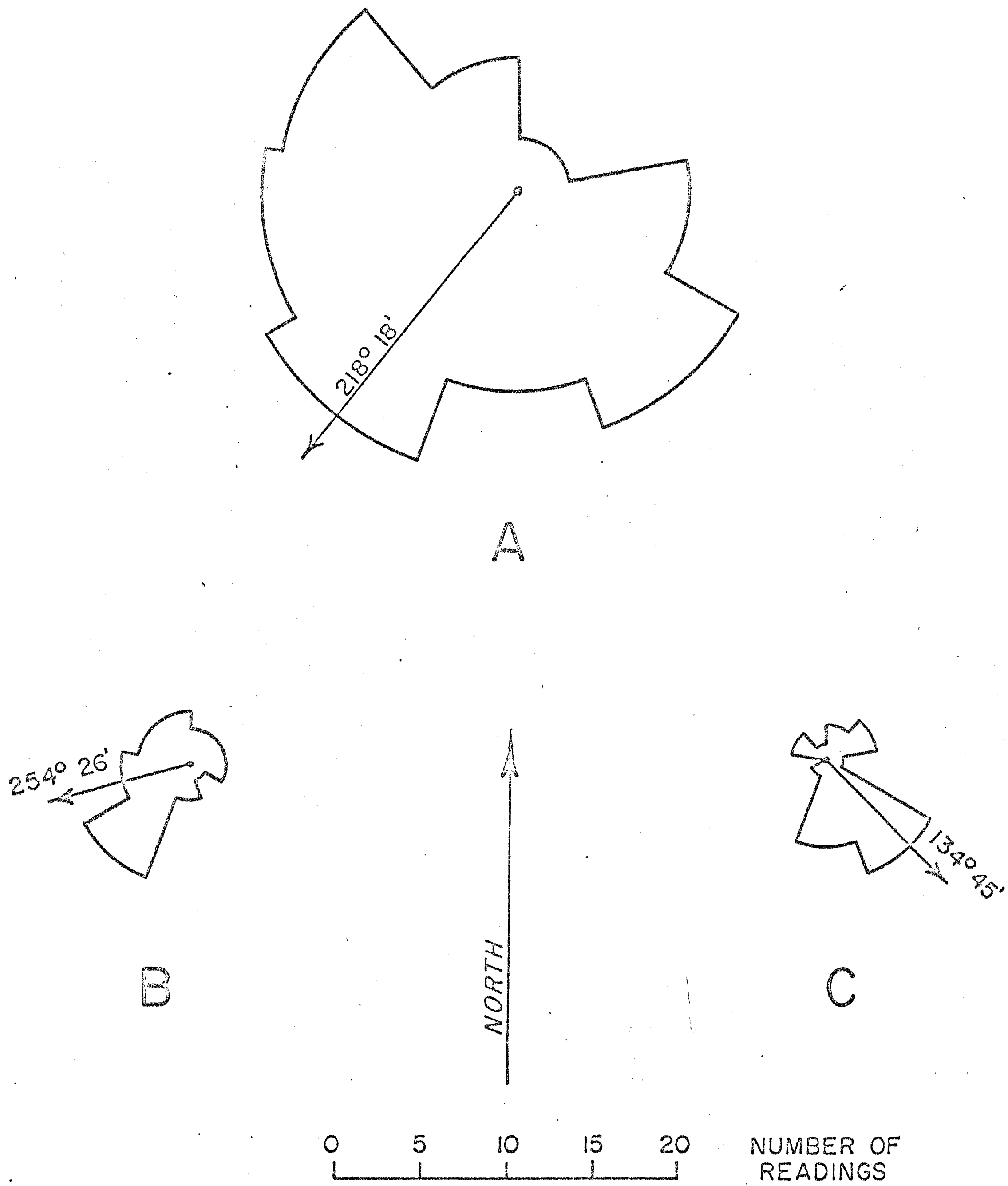

Figure 7. - Frequency distribution of lichen orientations by 40-degree intervals in the central Alaska Range, Alaska

A = Rhizocarpon geographicum in terminal area of Gulkana and College Glaciers.

B = Umbilicaria proboscidea in terminal area of Gulkana and College Glaciers.

C = Rhizocarpon geographicum on terminal and south lateral moraines of Canwell Glacier.

may be due to (1) wind direction (Mayo, 1963, fig. 4), (2) differences in temperature on rock faces during morning and afternoon in late winter and early spring, or (3) differences in the length of time that dew remains on southeast and southwest faces during warm seasons. Greater concentrations of small lichens occurred on undersurfaces of boulders where moisture is retained longer than on upper surfaces, but few large lichens are found on undersurfaces which do not receive direct radiation. Lichens in depressions where snow meltwater collects are conspicuously larger than those in drier areas. In depressions where snowbanks remain most of the summer, lichens are absent or stunted and widely scattered.

On the south lateral moraines of Canwell Glacier (fig. 7c) maximum-diameter Rhizocarpon geographicum tend to grow on southeast faces or in a direction which faces directly up the lateral moraines (fig. 5). This dominant orientation seems to discount the effect of wind, which blows in the down-glacier direction, and may be the result of local topography affecting the amount of direct radiation reaching the area. The effect of sunlight on lichen growth is shown by the rose diagrams of lichens in the Gulkana-College Glacier area (figs. 7a and 7b) which show most lichen growth to be on south-facing rock faces. In the terminal areas of Canwell and Black Rapids Glaciers, which are below tree-line, lichens receive much less direct radiation as previously indicated.

The effects of variations in lithology on lichen growth is not known in detail. This error was minimized by measuring lichens only on rocks of intermediate composition, such as diorite and quartz diorite. In the Gulkana-College Glacier area lichens do not grow on limestones or poorly indurated tuff boulders because these rocks spall and disintegrate rapidly in this alpine climate due to a large number of freeze and thaw cycles each year. On the south 1650(?) lateral moraine of Canwell Glacier (fig. 3) lichens are very stunted or absent on dunite boulders which have their source 6.4 to 7.2 km east of the Richardson Highway (Hanson, 1963). This stunted growth may be the result of either the basic composition of dunite or the rapid weathering of dunite in the central Alaska Range.

COMPARISON WITH RESULTS ELSEWHERE IN THE WORLD

The diameter of Rhizocarpon geographicum in the central Alaska Range increases slightly faster than in parts of the Alps, in Sweden, or in Norway (fig. 8), although the growth curve nearly parallels that of the Alps. Rhizocarpon geographicum apparently requires a longer period of time for initial colonization in the central Alaska Range than in Europe. These lichens on 1830 moraines in the central Alaska Range are approximately 30 mm in diameter but in the Alps they are about 80 mm. On 1650(?) moraines in the central Alaska Range the Rhizocarpon geographicum average 140 mm as compared to 174 mm in the Alps. Table 1 shows the comparison between the "lichen factor" for Rhizocarpon geographicum in the central Alaska Range and other parts of the world. The average increase of Rhizocarpon geographicum on three sets of moraines in the central Alaska Range is about 50 mm/century for the period of time between 1650(?) and 1830 and compares favorably to the rates measured elsewhere in the world.

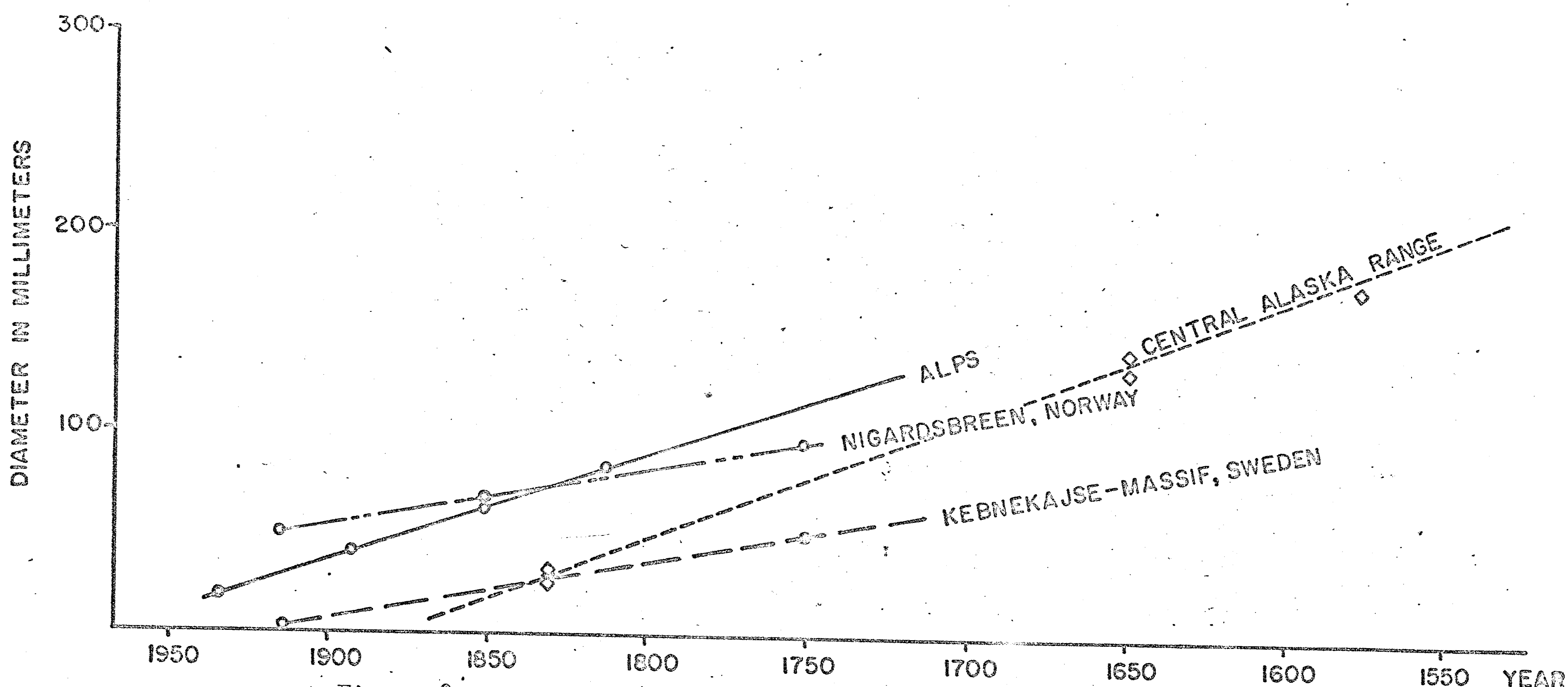

Figure 8. - Comparison of tentative growth rate curve for Rhizocarpon geographicum in the central Alaska Range (3 glaciers) with established growth rate curves in Europe (Compiled from Beschel, 1957).

Table I. Comparison of "lichen factors" of Rhizocarpon geographicum in various parts of the world. (After Andrews and Webber, 1964, Table I)

Region	Author	"Lichen factor" (mm per century)
Søndre Strømfiord area of Greenland	Beschel (1961b)	2 to 45
Baffin Island	Andrews and Webber (1964)	5.4
Greenland (Disko area)	Beschel (1963a)	15
Axel Heiberg	Beschel (1963b)	4 to 15
Italy (Gran Paradiso)	Beschel (1958b)	13 to 25
North Sweden	Stork (1963)	20
Austria	Beschel (1957a)	21 to 93
South Norway	Stork (1963)	46
Switzerland (Steingletscher)	Beschel (1957a)	60
Central Alaska Range	this study	50

The recent advances of Black Rapids, Castner, Canwell, Gulkana and College Glaciers correlate well and apparently occurred about 1580(?) (Gulkana Glacier), 1650(?), 1830 and 1875 (Gulkana and College Glaciers). Advances by small cirque glaciers in the nearby Amphitheater Mountains appear to be similar in age to the 1650(?) and 1830 advances in the Delta River area (Péwé, 1961, p. 201). Wahrhaftig (1958, p. 61-62) describes Recent moraines of Yanert Glacier and other glaciers in the vicinity of the Nenana River valley which probably correlate in part with the 1650(?) and 1830 advances. Hamilton (1965) describes similar advances in the south-central Brooks Range. Lawrence (1950), Ahlmann (1948) and Beschel (1961c) note advances of approximate 1830 age in Southeastern Alaska, Greenland, Europe and central Africa. The minor 1875 advance of Gulkana Glacier has no known correlative advances in the central Alaska Range, but Lawrence (1950, p. 219) shows similar advances in Southeastern Alaska. Ahlmann (1948, p. 72-73) illustrates correlative 1875 advances in Greenland, and according to Beschel (1961b, p. 1059), minor advances occurred in the Alps in the period 1870-1880. The periodic glacial advances from 1580 to 1875 in the central Alaska Range correlate well with the world wide cold epoch following the "climatic optimum" as outlined by Lamb (1964, p. 334-336).

CONCLUSIONS

Péwé initially dated the prominent 1830 and 1650(?) terminal moraines of Black Rapids, Castner and Canwell Glaciers in areas below tree-line by dendrochronology. In 1962 Reger measured lichen diameters on these moraines. Reliable results at Black Rapids Glacier were obtained only on the 1830 terminal moraine, so no growth curve is at present available for comparison with lichen growth curves from other glaciers in the central Alaska Range. Maximum-diameter Rhizocarpon geographicum on the 1830 terminal moraine of Black Rapids Glacier average 24 mm. A preliminary growth rate curve for Rhizocarpon geographicum was constructed in the Canwell Glacier area where the best results were obtained. Maximum-diameter Rhizocarpon geographicum on the 1830 moraine average 30 mm and on the 1650(?) moraine average 144 mm. The Recent moraines of Gulkana and College Glaciers are dated by comparison of maximum-diameter Rhizocarpon geographicum and were formed by advances in 1875, 1830, 1650(?) and 1580(?). Maximum-diameter Rhizocarpon geographicum in the Gulkana-College Glaciers area average 9 mm on 1875 moraines, 31 mm on 1830 moraines, 137 mm on 1650(?) moraines, and 177 mm on 1580(?) moraines.

The growth rates of Rhizocarpon geographicum in the central Alaska Range compare favorably with growth rates recorded in the Alps.

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